

Claims:

1. An expendable container capable of measuring a residual quantity of stored expendable, the expendable container comprising:

an expendable tank configured to store the expendable and has a piezoelectric element attached thereto;

a detection signal generation circuit configured to charge and discharge the piezoelectric element, and generate a detection signal including cycle information, the cycle information representing a cycle of an output voltage wave of the piezoelectric element after the discharge; and

a control module configured to control the charge and the discharge of the piezoelectric element by the detection signal generation circuit, wherein

the detection signal generation circuit comprises:

a comparator configured to compare a voltage of the output voltage wave with a reference voltage for residual quantity detection, and generate a pulse according to a result of the comparison; and

a signal generator configured to generate the detection signal in response to the generated pulse, wherein

the control module is capable of varying the reference voltage for residual quantity detection.

2. An expendable container capable of measuring a residual quantity of stored expendable, the expendable container comprising:

an expendable tank configured to store the expendable and has a piezoelectric element attached thereto;

a detection signal generation circuit configured to charge and discharge the piezoelectric element, and generate a detection signal including amplitude information, the amplitude information representing whether an amplitude of a remaining vibration of the piezoelectric element after the discharge is greater than a preset threshold value; and

a control module configured to control the charge and the discharge of the piezoelectric element by the detection signal generation circuit, wherein

the amplitude information is available for determining whether the residual quantity of the expendable is greater than a preset level, and

the control module is capable of varying the preset threshold value.

3. The expendable container in accordance with claim 2, wherein

the control module is configured to regulate at least one of a discharge time constant and a discharge time in the discharge of the piezoelectric element by the detection signal generation circuit, so as to vary a discharge characteristic of the piezoelectric element.

4. The expendable container in accordance with either one of claims 2 and 3, wherein

the detection signal generation circuit is configured to generate the detection signal according to a number of specific peaks, the specific peak

being an output voltage of the piezoelectric element after the discharge higher than a reference voltage for residual quantity detection as the preset threshold value.

5. The expendable container in accordance with claim 4, wherein the control module is configured to set the reference voltage for residual quantity detection to make the number of the specific peaks in a predetermined range, when the residual quantity of the expendable is greater than the preset level.

6. The expendable container in accordance with claim 4, wherein the control module is configured to set the reference voltage for residual quantity detection to make the number of the specific peaks equal to zero, when the residual quantity of the expendable is greater than the preset level.

7. The expendable container in accordance with any one of claims 1, 4, and 6, the expendable container further comprising:

a non-volatile memory configured to store setting information on the reference voltage for residual quantity detection, the setting information on the reference voltage for residual quantity detection representing a relation between the reference voltage for residual quantity detection and piezoelectric element characteristic information indicative of a characteristic of the piezoelectric element,

wherein the control module is capable of setting the reference voltage for residual quantity detection according to a given piece of the piezoelectric element characteristic information and the setting information on the reference voltage for residual quantity detection.

8. The expendable container in accordance with claim 7, wherein the piezoelectric element characteristic information is a rank selected among multiple ranks according to a measurement of the characteristic of the piezoelectric element, and

the control module is configured to set the reference voltage for residual quantity detection in response to the selected rank.

9. The expendable container in accordance with any one of claims 1 through 8, wherein

the control module controls has a test mode to control the detection signal generation circuit to measure an output voltage of the piezoelectric element after a preset time period has elapsed since a last charge or discharge operation of the piezoelectric element, and also to control the detection signal generation circuit to generate a failure detection signal according to a presence or absence of a specific peak where an output voltage wave of the piezoelectric element is higher than a reference voltage for function check.

10. The expendable container in accordance with claim 9, the

expendable container further comprising:

a non-volatile memory configured to store setting information on the reference voltage for function check, the setting information on the reference voltage for function check representing a relation between the reference voltage for function check and piezoelectric element characteristic information indicative of a characteristic of the piezoelectric element,

wherein the control module is capable of setting the reference voltage for function check according to a given piece of the piezoelectric element characteristic information and the setting information on the reference voltage for function check.

11. The expendable container in accordance with claim 10, wherein the piezoelectric element characteristic information is a rank selected among multiple ranks according to a measurement of a characteristic of the piezoelectric element, and

the control module is configured to set the reference voltage for function check in response to the selected rank.

12. A method of measuring a residual quantity of expendable stored in an expendable container, the method comprising the steps of:

(a) providing an expendable tank configured to store the expendable and has a piezoelectric element attached thereto, and a circuit configured to charge and discharge the piezoelectric element;

(b) setting a reference voltage for residual quantity detection which is

used for the measurement, in a variable manner; and

(c) carrying out the measurement,

the step (c) comprising:

(c-1) charging the piezoelectric element;

(c-2) discharging the piezoelectric element;

(c-3) comparing a voltage of an output voltage wave of the piezoelectric element after the discharge with the reference voltage for residual quantity detection, and generating a pulse according to a result of the comparison;

(c-4) generating a detection signal including cycle information in response to the pulse, the cycle information representing a cycle of the pulse; and

(c-5) determining whether the residual quantity of the expendable stored in the expendable container is greater than a preset level, in response to the detection signal.

13. A method of measuring a residual quantity of expendable stored in an expendable container, the method comprising the steps of:

(a) providing an expendable tank configured to store the expendable and has a piezoelectric element attached thereto, and a circuit configured to charge and discharge the piezoelectric element;

(b) setting a preset threshold value used for the measurement, in a variable manner; and

(c) carrying out the measurement,

the step (c) comprising:

(c-1) charging the piezoelectric element;

(c-2) discharging the piezoelectric element;

(c-3) generating a detection signal including amplitude information, the amplitude information representing whether an amplitude of a remaining vibration of the piezoelectric element after the discharge is greater than the preset threshold value; and

(c-4) determining whether the residual quantity of the expendable stored in the expendable container is greater than a preset level, in response to the detection signal.

14. A computer program for causing a computer to control an expendable container to set a reference voltage for measuring a residual quantity of stored expendable, the expendable container being capable of the measuring, wherein

the expendable container comprising:

an expendable tank configured to store the expendable and has a piezoelectric element attached thereto;

a detection signal generation circuit configured to charge and discharge the piezoelectric element and generate a detection signal including cycle information, cycle information representing a cycle of an output voltage wave of the piezoelectric element after the discharge;

a control module configured to control the charge and the discharge of the piezoelectric element; and

a non-volatile memory configured to store setting information and residual quantity information, the setting information representing a current setting of the reference voltage for residual quantity detection, the residual quantity information representing whether the residual quantity of the expendable is greater than a preset level,

the computer program for causing the computer to carry out the functions of:

(a) reading out the setting information and the residual quantity information from the non-volatile memory;

(b) setting the reference voltage for residual quantity detection, based on the setting information;

(c) confirming that the residual quantity of the expendable is greater than the preset level, based on the residual quantity information;

(d) generating a detection signal including information representing a cycle of a remaining vibration of the piezoelectric element after the discharge, in response to the confirmation;

(e) receiving the detection signal, and determining whether the residual quantity of the expendable is measurable, in response to the received detection signal;

(f) setting a different voltage from the current setting to the reference voltage for residual quantity detection, and returning a process to the function (d), in response to the determination that the residual quantity of the expendable is immeasurable; and

(g) recording the setting information representing the current setting

of the reference voltage for residual quantity detection into the non-volatile memory, in response to the determination that the residual quantity of the expendable is measurable.

15. A computer program for causing a computer to control an expendable container to set a reference voltage for measuring a residual quantity of stored expendable, the expendable container being capable of the measuring, wherein

the expendable container comprising:

an expendable tank configured to store the expendable and has a piezoelectric element attached thereto;

a detection signal generation circuit configured to charge and discharge the piezoelectric element, and generate a detection signal including amplitude information, the amplitude information representing whether an amplitude of a remaining vibration of the piezoelectric element after the discharge is greater than a preset threshold value;

a control module configured to control the charge and the discharge of the piezoelectric element; and

a non-volatile memory configured to store setting information and residual quantity information, the setting information representing a current setting of the reference voltage for residual quantity detection, the residual quantity information representing whether the residual quantity of the expendable is greater than a preset level,

the computer program for causing the computer to carry out the

functions of:

(a) reading out the setting information and the residual quantity information from the non-volatile memory;

(b) setting the reference voltage for residual quantity detection, based on the setting information;

(c) confirming that the residual quantity of the expendable is greater than the preset level, based on the residual quantity information;

(d) generating a detection signal including information representing a cycle of a remaining vibration of the piezoelectric element after the discharge, in response to the confirmation;

(e) receiving the detection signal, and determining whether the residual quantity of the expendable is measurable, in response to the received detection signal;

(f) setting a different value from the current setting to the threshold value and returning a process to the function (d), in response to the determination that the residual quantity of the expendable is immeasurable; and

(g) recording the setting information representing the current setting of the threshold value into the non-volatile memory, in response to the determination that the residual quantity of the expendable is measurable.